May 20, 1958 C. D. MURDOCH ET AL 2,835,549

GRAPHICAL RECORDING APPARATUS

Filed March 28, 1955 3 Sheets-Sheet 1

Fig - 2

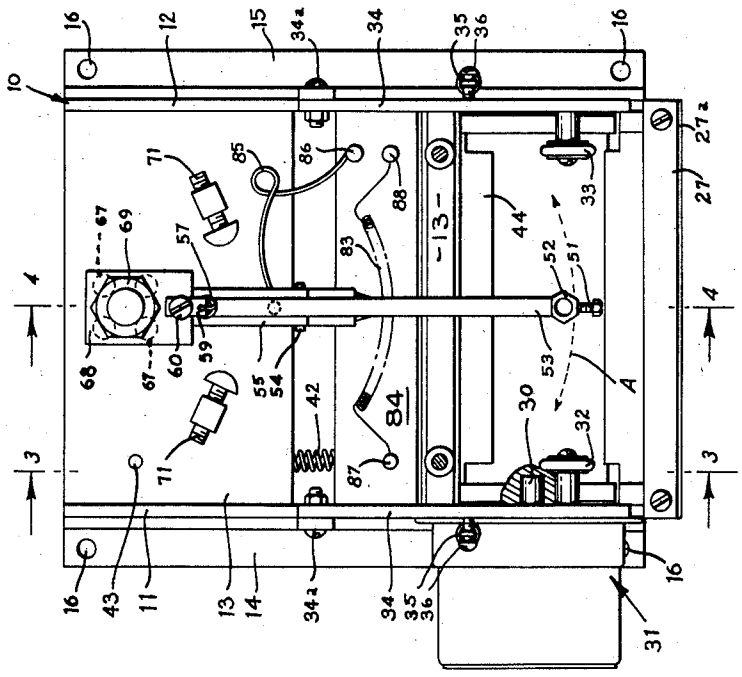
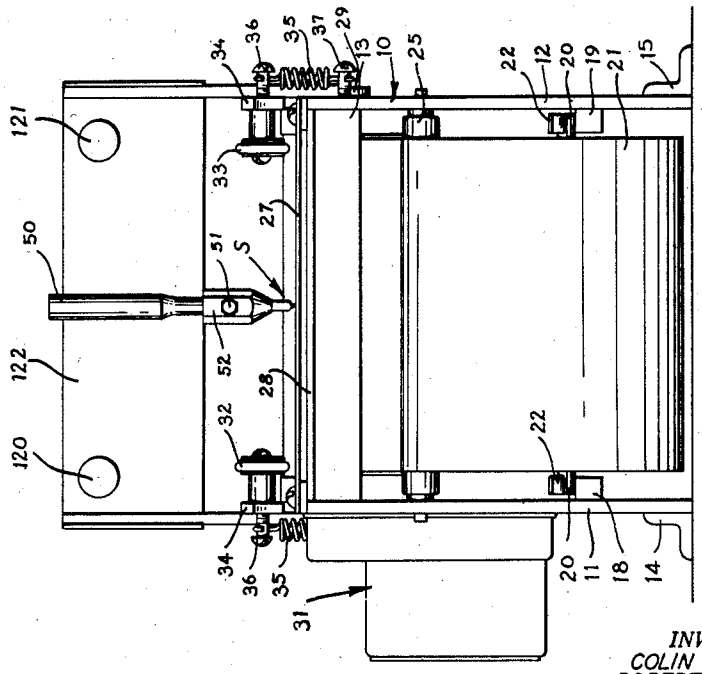


Fig - 1



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Filed March 28, 1955 3 Sheets-Sheet 2

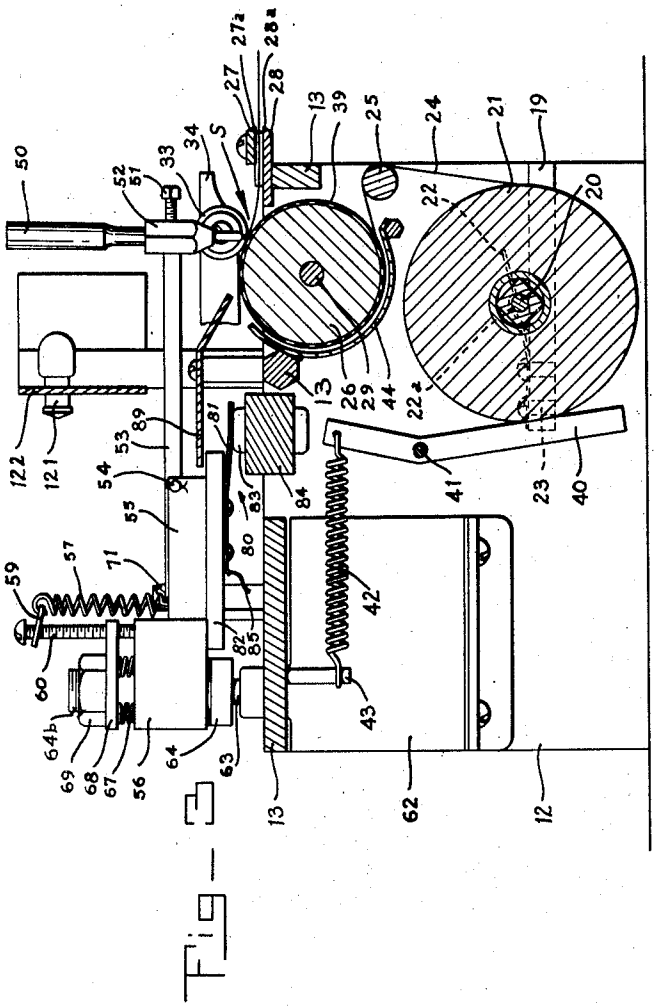


Fig. 3

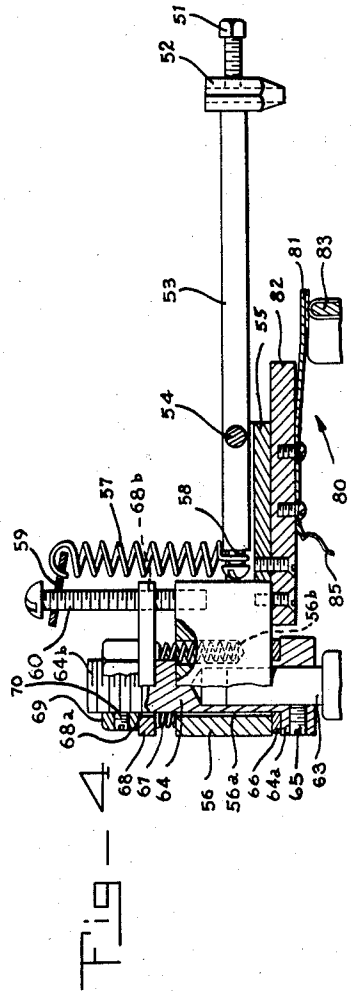


Fig. 4

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GRAPHICAL RECORDING APPARATUS

Filed March 28, 1955 3 Sheets-Sheet 3

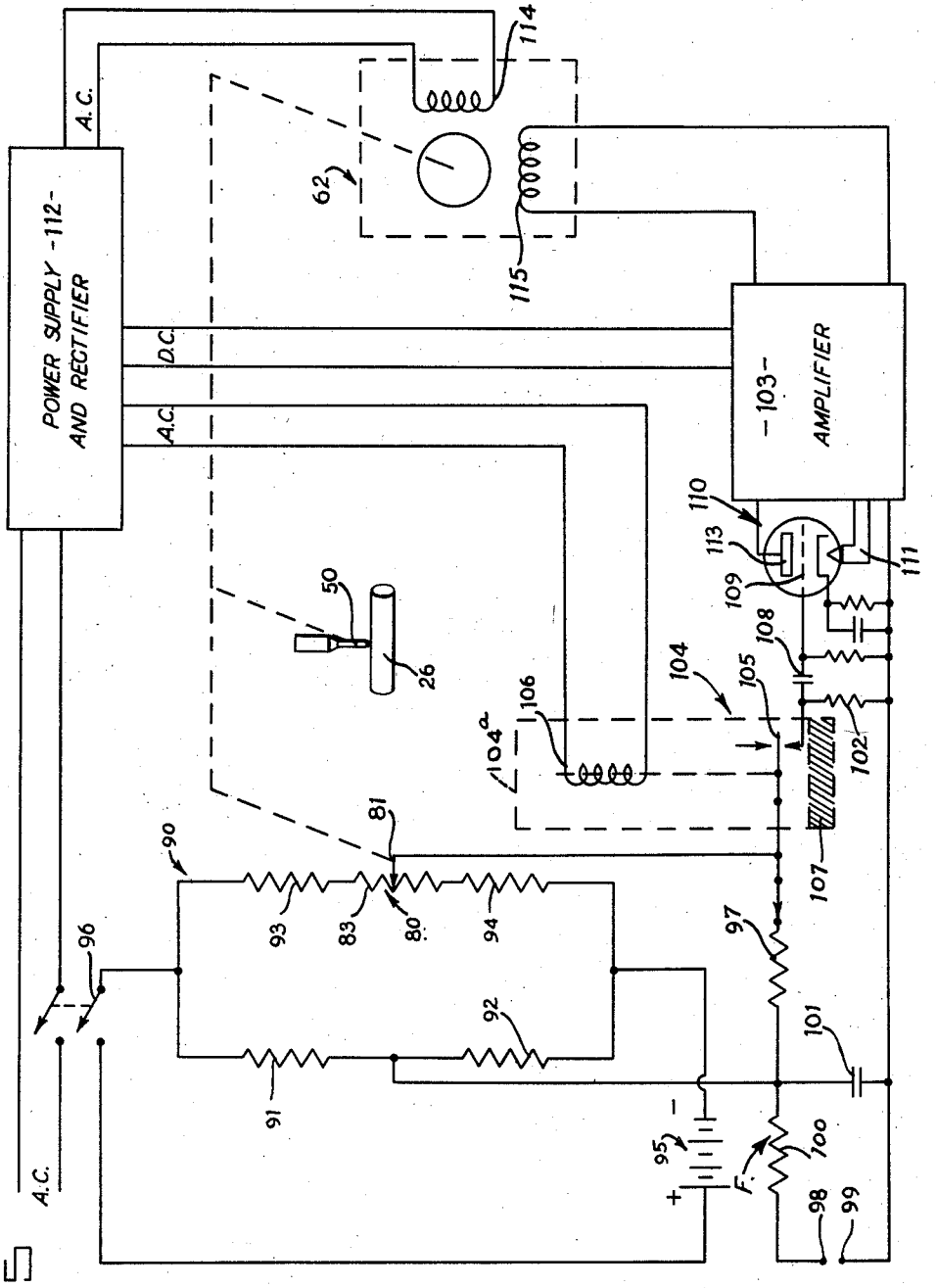


Fig-5

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2,835,549

GRAPHICAL RECORDING APPARATUS

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Application March 28, 1955, Serial No. 497,346

2 Claims. (Cl. 346—32)

The present invention relates to recording apparatus, and, more particularly, to apparatus for providing a permanent graphical record of the magnitude and variation in magnitude and polarity of very small currents or voltages such as produced by thermocouples, thermopiles, photoelectric cells and the like.

It is an object of the invention to provide a recording apparatus, that is relatively simple and inexpensive yet which has a high degree of accuracy and sensitivity in the recording of very small currents or voltages.

Another object is to provide a graphical recorder having a pen or stylus associated with a moving strip of graph paper in a manner to produce a clear and distinct linear marking on the paper.

A further object of the invention is to provide an improved arrangement for feeding the strip of graph paper to and past the pen or marking stylus in a positive, controlled manner.

It is another object to provide a simple, direct mechanism for causing lateral displacement of the pen or stylus with respect to the moving graph in response to a change in the magnitude of a signal current or voltage which is to be recorded.

Yet a further object is to provide this pen-displacing mechanism with a fractional drive connection that enables limitation of the pen displacement regardless of the magnitude of the signal and thus obviates the necessity for the employment of electrical limit switches or the like.

It is another object of the invention to provide a recording apparatus which provides for automatic readjustment of the recording pen after the same has been accidentally or purposefully displaced from its proper position as determined by the signal current or voltage.

A further object is to provide a simple but effective arrangement for amplifying the signal to be recorded prior to its application to the pen-displacing mechanism.

These and other objects as well as the attendant advantages of the invention will become more apparent from a perusal of the following description of a preferred embodiment of the invention shown in the accompanying drawings wherein:

Fig. 1 is a front elevation of a recording apparatus constructed in accordance with the invention, certain parts thereof being broken away to expose details of construction,

Fig. 2 is a plan view of the recording apparatus, with certain parts broken away to expose details underneath,

Fig. 3 is a section through the apparatus, taken along line 3—3 of Fig. 2,

Fig. 4 is a fragmentary sectional view of the pen-displacing mechanism taken along line 4—4 of Figure 2, and

Fig. 5 is a schematic diagram of an electronic circuit utilized to amplify the signals to be recorded, and indicating diagrammatically the association of said circuit with the mechanical elements of the recording apparatus.

As shown in Figs. 1, 2 and 3, the recording apparatus includes a generally rectangular frame **10** composed of

side plates **11**, **12** held in spaced parallel relation by several transversely extending struts **13** of various shapes designed to accommodate the components of the apparatus. Small angle irons **14**, **15** are attached to the side plates **11**, **12** along their lower edges as shown in Fig. 1 and are provided with holes **16** so that the frame **10** can be bolted firmly to a horizontal surface with the side plates **11**, **12** rising vertically therefrom.

Bars **18**, **19** are attached, as by welding, to the interior of the side plates **11**, **12**, respectively, so as to extend rearwardly from the front of the apparatus and support the ends of a shaft **20** on which a roll **21** of graph paper is mounted for rotation. In order to hold the shaft **20** in the required position on the bars **18**, **19**, a leaf spring **22** having an indented portion **22***a* is secured by screws **23** to the inner or rearward end of each of the bars **18**, **19** and projects forwardly over the shaft **20** with the indented portion **22***a* resiliently embracing said shaft so that it functions as a spring detent. This detent arrangement for positioning the shaft **20** enables its ready withdrawal and reinsertion when a new roll of graph paper is required.

The graph paper is pulled from the roll **21** upwardly along a sinuous path, as indicated at **24** in Fig. 3, to and beyond a marking point or station S whereat the paper is marked in accordance with the condition to be recorded, as will be explained in detail hereinafter. The paper first passes upwardly and over a small idler roller **25** journalled in the side plates **11**, **12** adjacent the front of the apparatus and thereafter passes rearwardly and around a larger roller **26** to emerge once more at the front where it is threaded between two superposed horizontally positioned plates **27**, **28** that are rigidly secured to the frame in spaced relation and which have knife edges as indicated at **27***a* and **28***a*, along which the paper strip may be torn off, if desired. The larger roller **26** is the drive roller for the paper and is secured at one end on a stub shaft **29** journalled in side plate **12** and at the other end on the inwardly projecting shaft **30** of a drive unit **31** which is mounted on the outside of the other side plate **11**, as shown in Figs. 1 and 2, and includes a motor, speed reduction gearing, and an overrunning clutch of conventional design. Rubber rings **32**, **33** are disposed in spaced relation radially above and adjacent the edge area of the drive roller **26**. Each ring is mounted for rotation at the forward end of a bar **34** that is pivoted at its remote end **34***a* on a respective one of the side plates **11**, **12** and urged downwardly by a small coil spring **35** (Fig. 1) tensioned between projections **36** and **37** on the pivoted bar **34** and the adjacent stationary side plate **11** or **12**, respectively. Consequently the rings **32**, **33** will press the graph paper against the surface of the drive roller **26** to establish driving relationship therebetween. Hence, when the roller **26** rotates, the paper will be pulled continuously from the supply roll **21** along the described sinuous path **24**.

To further enhance the traction between the drive roller **26** and the paper, the surface of said roller may be made resilient as by the application of a rubber covering **39** (Fig. 3) and the graph paper is placed under tension so that it is urged against the surface of the drive roller **26** throughout its entire contact therewith and not merely at the point where the rings **32**, **33** press thereagainst. To provide the desired tension, an arm **40** is pivotally mounted as indicated at **41** on the side plate **12** so as to be urged laterally against the supply roll **21** by a spring **42** tensioned between its far end and a stationary stud **43** projecting downwardly from one of the previously described transverse struts **13**. In this manner, a drag is placed on the movement of the supply roll **21** and the paper dispensed from said roll is under a continuous steady tension so as to be urged into driving engagement

with the rubber-covered drive roller **26**. As the supply roll **21** is gradually depleted and its diameter decreases, the drag arm **40** pivots under the urgency of the spring **42** and thus maintains its contact with the roll **21**. However, as the size of the paper supply roll **21** decreases, the point of contact between the arm **40** and the roll moves away from the pivot **42** of the arm, and this together with the progressive relaxation of the spring **42** is effective to reduce the force of the drag exerted by the arm **40** upon the paper roll **21**. This is a highly desirable effect because as the radial size of the paper roll **21** decreases, the tangential pull of the unwound paper strip which turns the roll **21** loses progressively its mechanical advantage, and a greater effort on the part of the drive unit **31** would ordinarily be required to unwind the roll and supply the paper strip at the same rate to and past the marking station S. This may overload the motor of the drive unit and may cause the paper strip to break. Due to the automatic reduction of the tensioning drag exerted upon the paper supply roll **21** by the above described arrangement, said roll may at all times be unwound with substantially the same effort and as a result there is no danger that the paper strip may tear or that the motor of the drive unit be overloaded.

After a roll of graph paper is entirely depleted, the supporting shaft **20** therefor can be manually pulled forwardly from its position on the bars **18**, **19** under the leaf springs **22**, and a new roll may then be placed on the shaft. Thereafter, the shaft **20** with the new roll thereon is placed on the bars **18**, **19** and pushed rearwardly until the springs **22** snap into their restraining engagement with the shaft **20**. The drag arm **40** automatically adjusts its position in accordance with the diameter of the newly-inserted roll **21**. After the roll **21** is properly inserted, the paper is pulled upwardly and passed around the idler roller and then pushed inwardly beneath the drive roller **26**.

A curved plate **44** is rigidly supported between the side plates **11** and **12** to surround the lower and rear portions of the drive roller **26** in spaced relation thereto so that the paper is automatically directed around the drive roller when pushed thereunder as described. The leading edge of the graph paper, upon arrival at the top of the drive roller **26**, is carefully fed under the rubber rings **32**, **33** by manual rotation of the drive roller in a clockwise direction, as viewed in Fig. 3. The aforementioned overrunning clutch included in the drive unit **31** permits such rotation whether the motor is energized or not. Finally, the paper is passed between the plates **27** and **28** at the front of the frame **10** and the newly-inserted graph paper is in readiness to receive the markings that provide the permanent recording of the condition to which the apparatus is responsive.

The markings are applied to the paper by a suitable instrument at the previously mentioned marking station S which is located adjacent the rings **32**, **33** at the top of the drive roller **26**. As shown, a ball point pen **50** is clamped by a set screw **51** within a tubular socket **52** supported in substantially a vertical position at the end of an arm **53**. This pen-supporting arm **53** projects forwardly above the frame **10** from its pivotal mounting on a pin **54** which horizontally bridges the upturned legs of a channel member **55** and the channel member is, in turn, attached to a block **56** arranged to pivot about a vertical axis. As a consequence the pen **50** supported by the described structure can move vertically about the axis of the pin **54** and horizontally about the axis of the block **56** along an arc A as delineated in Fig. 2.

To assure that the pen **50** will produce clear and continuous markings on the graph paper, it is urged against the paper with a predetermined amount of force by a spring **57**. As best shown in Fig. 4, this spring **57** is attached to the end of the pen-supporting arm **53** remote from the pen itself by means of a screw **58** and is stretched vertically between this point of connection and a small plate **59** attached to a long screw **60** that rises from the aforementioned mounting block **56**. The plate **59** is provided with an opening encompassing the screw **60** somewhat loosely so that attachment therebetween is effected by action of the spring **57** which pulls the plate into the illustrated angular disposition whereat it is wedged against the screw. A manual release of the spring tension will enable the quick adjustment of the position of the plate **59** on the screw **60** and a resultant change in the force urging the pen **50** against the graph paper. The force of the pen **50** against the paper is preferably set at about five ounces and this pressed engagement of the pen against the paper in conjunction with the cushioned support of the paper provided by the previously described rubber covering **39** on the drive roller **26** assures the desired continuity and clarity of the markings. This will be true regardless of the lateral disposition of the pen along the arc A, previously mentioned, for although movement of the pen along this arc necessitates a slight vertical movement of the pen to accommodate the curvature of the paper-supporting roller **26**, vertical self-adjustment is automatically accomplished because of the permitted vertical pivoting of the pen-supporting arm **53** and the resilience of the spring **57** which urges the pen **50** into contact with the roller. It should here also be noted (Fig. 3) that the location of pen **50** is so chosen that its point contacts the paper strip in a region slightly in front of the points of contact of the traction rings **32**, **33** with the paper strip on drive roller **26** as viewed in the direction of advance of said strip. Hence, the paper strip will be pulled, rather than pushed, underneath the pen point, and as a result thereof the pen may be pressed against the paper strip with a relatively high force, as mentioned hereinbefore, without danger that the paper strip may buckle as it might if it were pushed underneath the pen point.

The pen **50** is caused to move laterally along the described arc A in response to the excitation of an electric motor **62** which is bolted to one of the transverse struts **13** at the rear of the frame **10** so that its shaft **63** projects upwardly into a bore **56***a* in the hereinbefore described mounting block **56** and defines the previously mentioned vertical axis about which the pen **50** can move. The motor **62** is of the conventional two phase type and incorporates suitable reduction gearing so that 500 turns of the motor armature are required to effect a single turn of the projecting shaft **63**. A sleeve **64** is held on the upwardly projecting shaft **63** by means of a set screw **65** that lies within a threaded radial bore in a lateral flange **64***a* at the lower end of the sleeve (Fig. 4). A friction washer **66** lies on top of this flange **64***a* and the described mounting block **56** rests thereon with its bore **56***a* loosely encompassing the sleeve **64** and the shaft **63** therein. Four cylindrical recesses **56***b* are formed in the block **56** to extend from its top downwardly at spaced intervals around the central bore **56***a*, only one of said recesses **56***b* being visible in Fig. 4. Each recess **56***b* receives a coil spring **67** that projects above the top of the block **56** and bears against a superposed plate **68** which has an opening **68***a* that loosely encompasses the sleeve **64** adjacent its upper end which is threaded as indicated at **64***b*. A nut **69** is screwed onto the upper threaded end **64***b* of the sleeve **64** so as to engage the plate **68** and compress the springs **67** between said plate and the bottom of the cylindrical recesses **56***b* in the mounting block **56**. When the springs **67** are so compressed, the mounting block **56** is pressed against the friction washer **66** and the friction washer is, in turn, urged with the same force against the flange **64***a* on the sleeve **64** whereby a frictional driving connection is established between the mounting block **56** and the sleeve **64**. The same frictional driving connection exists between the plate **68** and the nut **69**. After the nut **69** has been screwed onto the sleeve **64** to produce the desired compression of the springs **67**, it is locked on the sleeve by a set screw **70**.

When the motor shaft **63** rotates, the sleeve **64** rotates therewith and the mounting block **56** is caused to rotate as a result of its frictional connection through the washer **66** to said sleeve. All of the structure supported on the mounting block **56** accordingly rotates about the vertical axis of shaft **63** and the pen **50** moves along the arc A. The compression plate **68** above the mounting block **56** also rotates as it is provided at its forward end with a small hole **68***b* through which the aforementioned elongated screw **60** passes to preclude rotary displacement of the two members relative to each other.

The lateral movement of the pen **50** is limited by means of adjustable stops **71** (Fig. 2), supported rigidly on one of the transverse struts **13** of frame **10**, on opposite sides of the channel member **55** that mounts the pen-supporting arm **53**. If the motor shaft **63** continues to rotate after the channel member **55** has engaged one of the stops **71**, the described frictional drive connection between said shaft and the mounting block **56** will slip so that the pen **50** will stop its movement while the motor **62** continues to revolve. The nut **69** above the compression plate **68** is adjusted to produce a yieldable compressive force that will enable such slippage without overloading of the motor.

The shaft **63** of motor **62** is revolved in response to a signal voltage or current that is to be recorded and is supplied in amplified form to the motor **62** through an electronic circuit, as shown diagrammatically in Fig. 5. Since, as above described, the rotative position of the motor shaft **63** can be displaced relative to the pen position as a result of the permitted slippage, the excitation of the motor **62** in response to the applied signal voltage or current is automatically adjusted in accordance with the precise position of the pen **50** at the time of excitation.

To provide for such automatic adjustment, a potentiometer **80**, incorporated in the circuit, is arranged so that its voltage output varies in accordance with a change in the pen position. As shown in Figs. 2, 3 and 4, the potentiometer **80** includes a leaf spring **81** which is mounted by an insulator **82** on the underside of the channel member **55** that shifts laterally with the pen **50**. The free end of the leaf spring **81** resiliently engages the top of an arcuately extending resistance coil **83** rigidly supported on the frame **10** by an insulating block **84**. As the pen **50** moves laterally along arc A, the leaf spring **81** moves a correlated amount along the coil **83**. A wire **85** connects the leaf spring **81** to a terminal post **86** and the ends of the coil **83** are connected respectively to terminal posts **87** and **88** on the insulating block **84**, as shown best in Fig. 2. A shield **89** (Fig. 3) is secured to the frame **10** immediately above the resistance coil **83** to avoid the deposit of dust thereon so that good electrical contact can be made.

Suitable wire (not shown) connect these terminal posts **86**, **87** and **88** to the electronic circuit shown in Fig. 5 in such a manner that the potentiometer **80** becomes part of a bridge circuit **90** which includes fixed resistors **91**, **92**, **93** and **94**. A direct current voltage is applied to the bridge circuit **90** from a standard cell **95** upon closure of one element of a ganged switch **96**. The bridge output is applied across a resistor **97**, one output contact being that furnished by engagement of the leaf spring **81** with the potentiometer coil **83**. When the pen **50** is centered on the graph paper, the bridge is in balance and no voltage appears across the output resistor **97**. However, as soon as the pen moves laterally, the leaf spring **81** moves along the coil **83** which unbalances the bridge and establishes a voltage across the output resistor **97**, the polarity of the voltage being determined by the direction of pen movement and the voltage amplitude being determined by the amount of such movement.

Depending upon its polarity, this bridge output voltage is arranged to add to or subtract from a signal voltage which is to be recorded. As shown, a direct current signal voltage that may be the output of a pair of thermopiles, is applied to terminals **98**, **99** to be supplied to a series circuit which includes the bridge output resistor **97**. Said series circuit includes also a resistor **100**, which forms with a capacitor **101** a filter F adapted to remove any spurious electronic noise that might be applied to the terminals **98**, **99** with the direct current input voltage. The series circuit contains an additional resistor **102** and the voltage developed across said resistor **102** constitutes the input to a multi-stage amplifier **103**.

The described series circuit is intermittently opened and closed by a vibrator **104** whose movable contact **105** is cyclically operated by an alternating current applied to the vibrator coil **106**. Mechanical vibration or "chattering" of the movable contact **105** is damped by the attachment of a weight **107** to the vibrator case **104***a*, as indicated diagrammatically in Fig. 5, which increases the inertia mass of said case.

As a result of the vibrator action, the differential voltage derived from the applied signal and the voltage appearing across the bridge output resistor **97** is applied through coupling capacitor **108** to the grid **109** of the first amplifier tube **110** (across resistor **102**) as an interrupted or pulsating direct current voltage having a square wave shape. Both the polarity and amplitude of this square wave voltage will be determined from the respective polarities and amplitudes of the signal voltage and the voltage appearing across the bridge output resistor **97**.

The amplifier **103** is of conventional design so that although it contains preferably five or more stages, only one is indicated for purposes of illustration. The amplifier is arranged to be highly selective so that amplification is obtained only at the fundamental frequency of the applied square wave voltage. Consequently, since little amplification of the harmonic components of the square wave is obtained, the output of the amplifier **103** is substantially a pure sine wave at the fundamental frequency. For best results, the amplifier **103** should be shielded to prevent the pick up of stray noise voltages from the atmosphere and should be rigidly assembled to preclude the production of microphonic voltages that result from the vibration of tube elements. To further reduce electronic noise and thus achieve a high degree of sensitivity, the tube filaments **111** should be heated with highly regulated direct current which is obtained from a suitable power supply **112** together with well regulated direct current voltages for the anode of plate **113** of each tube.

This power supply **112** is connected to the alternating current line voltage when the previously mentioned ganged switch **96** is closed to energize the bridge circuit **90**, as previously described. A portion of the voltage is rectified and directed to the amplifier **103** to supply the mentioned plate and filament voltages. Other portions of the supplied voltage are merely filtered and directed to the vibrator **104** and to one field coil **114** of the previously mentioned two phase electric motor **62** so that synchronization is established therebetween.

The other field coil **115** of the two phase motor **62** is energized by the output of the amplifier **103** and to provide the desired phase relationship, the amplifier embodies a suitable network (not shown) which shifts the phase of the applied square wave voltage by 90°. As a consequence, depending upon the polarity of the applied square wave voltage, the sine wave output of the amplifier **103** will lead or lag the line voltage as applied to the first field coil **114** by 90°. If the amplified signal voltage leads the line voltage, the motor shaft **63** will rotate in one direction; if the signal voltage lags, the shaft **63** will rotate in the reverse direction.

When the motor shaft rotates in one direction, the pen **50** moves along the arc A and simultaneously the leaf spring **81** shifts along the resistance coil **83**, the mechanical connection between these elements being diagrammatically shown in Fig. 5. As the contact point on

the coil 83 changes, the bridge output across the resistor 97 varies a corresponding amount. The polarity of the standard cell 95 is such that as the point of contact shifts in response to an applied signal voltage of, for example, a positive polarity, the bridge output constitutes an increasing voltage of negative polarity. Thus, when the bridge output voltage equals the signal voltage in absolute value and therefore reduces the voltage applied to the amplifier 103 to zero, no further excitation of the second field coil 115 exists and the motor shaft 63 ceases to rotate.

From the foregoing, it can be seen that excitation of the motor 62 is dependent both on the pen position and on the applied signal voltage so that a change in the pen position alone or a change in the signal voltage alone excites or energizes the motor to re-establish the proper relationship therebetween. In more concrete terms, this means that if, for example, the pen 50 is pushed, either purposefully or accidentally, from a position correlated with a constant signal voltage, the motor 62 is immediately energized to return the pen to its orginal correlated position. On the other hand, if an excessive signal voltage is applied such that lateral movement of the pen 50 is stopped before such signal voltage is equalled by the opposing voltage developed across the bridge output resistor 97, the motor shaft 63 continues to turn until said voltage is reduced, slippage being permitted by the frictional driving connection between the shaft 63 and the mounting block 56 for the pen structure as previously described. When the signal voltage drops below the value correlated with the limit of pen movement, the motor shaft 63 again moves the pen 50 and the signal voltage and bridge output voltage tend to equalize so that the signal voltage and pen position will be correlated properly regardless of the fact that the pen 50 could not "tract" the signal voltage to its excessive value.

In operation, a switch (not shown) is closed to energize the graph paper drive unit 31 and the ganged switch 96 (Fig. 5) is then closed to energize the power supply 112 for the pen-displacing motor 62 and the amplifier 103 and for the bridge circuit 90. Such energization is indicated by pilot lights 120, 121 mounted on a supporting plate 122 on the frame 10 above the pen-supporting arm 53. A signal may now be applied to the input terminals 98, 99 of the filter circuit F and the amplitude and polarity of this signal cause the pen-displacing motor 62 to move the pen 50 quickly to a position which is directly correlated with said signal amplitude and polarity, as previously explained. Any change in the signal is faithfully represented by a consequent shifting of the pen 50. After the desired record has been made, the end of the graph paper can be pulled out, since the paper drive unit 31 contains an overrunning clutch, and then torn off on the edge 27*a* or 28*a* of one of the plates 27, 28 by either an upward or downward pull.

Various modifications and alterations can be made in the described structure without departing from the spirit of the invention, and the foregoing description of one embodiment thereof is to be considered purely as exemplary and not in a limiting sense.

We claim:

1. A graphical recording apparatus comprising a reversible motor having a vertically disposed output shaft, an apertured block loosely engaged over said output shaft, a channel member rigidly secured to and projecting from said block in a direction radially of said vertically disposed shaft, an arm fitted into said channel member and projecting beyond the free end thereof, said arm being pivotally supported from said channel member for rotation about a transverse horizontal axis, a marking member supported from the projecting end of said arm, a drive roller mounted for rotation about a horizontal axis parallel to the axis of rotation of said arm and arranged to support a band of paper for movement underneath said marking member, spring means urging said marking member into marking engagement with the paper on said drive roller, stop means at either side of said channel member a predetermined angular distance from a predetermined center position thereof, and adjustable spring means yieldably urging said block into engagement with said drive shaft for rotation therewith through the angular interval determined by said stop means.

2. A graphical recording apparatus comprising a reversible motor having a first and a second field winding and a vertically disposed output shaft, an arm mounted for pivotal movement about a horizontal axis supported from said shaft for rotation therewith about its vertical axis, a marking member supported from said arm, drive means arranged to support a band of paper for movement underneath said marking member, spring means urging said marking member into marking engagement with the paper on said drive means, and means for energizing said motor in accordance with a signal voltage to be recorded, including means for applying a voltage to said first field winding, an electric circuit to which the signal voltage may be applied, a bridge circuit having means for applying a voltage thereto and a potentiometer whose contact arm is connected to said marking-member-supporting arm for movement therewith about the axis of said reversible motor shaft so that the output of said bridge circuit varies with movement of said supporting arm, and means for applying the varying output of said bridge circuit to said electric circuit in series with the applied signal voltage, and means for applying the differential voltage derived from the applied signal and the output of said bridge circuit at a phase difference to said second field winding.

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